Research briefing

The health and economic impacts of toxic air in Liverpool City Region

A British Lung Foundation briefing based on existing evidence and featuring new findings from Liverpool City Region Combined Authority health and economic impact assessment study (2019), carried out by King's College London.

January 2020
blf.org.uk/policy

Credit and thanks

This briefing has been produced by the British Lung Foundation. It takes findings from Liverpool City Region Combined Authority health and economic impact assessment study (2019), carried out by King's College London and commissioned by the BLF – www.erg.kcl.ac.uk/Research/home/projects/Liverpool.html

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With special thanks to Alexia Zavros, Pam Parry and Safiyah Kamarudin for sharing their stories.

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Jace and Teyha, Alexia's children

Foreword

I've lived in Liverpool my whole life and have been concerned with air pollution for as long as I can remember. When I became a parent ten years ago, I became even more worried. My daughter kept developing chest infections and regularly ended up needing antibiotics. She lives in a smoke-free home and we couldn't work out why she was struggling with so many chest complaints.

Our doctor said this was linked to us living in a highly congested part of Liverpool. He said that many of his patients in the local area had similar recurring chest problems. My daughter also developed eczema that would clear up when we went camping or travelled abroad – again our doctor suggested this is likely to be a result of her environment. I also have a one-year old son and even simple things like a walk in our local park leaves me feeling guilty for walking him across a dual carriageway full of smog so he can get into nature and play.

The more I read up on this, the more I learnt about how damaging pollution is for our health. We seem to be finding out more and more every day. You try to do everything you can to protect your children, that's why I joined the Clean Air Parents' Network and have been campaigning to clean up the toxic air we're breathing in Liverpool.

We're trying to do all we can as a family to help tackle the problem. I don't drive, we walk to school and the shops. But then it feels very unfair that as pedestrians we continue to be highly exposed to toxic air. There seems to be much more that politicians could be doing to tackle air pollution, for instance, closing the road outside my daughter's school, improving our public transport, setting out new clean air laws and pedestrianizing shopping areas. Without these basic measures, I fear for the younger generation.

It's great to see this report shine a light on the problem in Liverpool City Region. Our children's lives are far too precious for them to be damaged by something we can change. And the problem has been going on for far too long – I hope this is the push our politicians need to finally take action.

Alexia Zavroz, mum of two and clean air campaigner, from Liverpool

Executive summary

Air pollution is now recognised by the UK government as the "greatest environmental harm to our health."[1] We have been breaching legal limits for a harmful gas known as nitrogen dioxide (NO_2) since 2010 and while progress has been made, we are still a long way from meeting these limits in most of our towns and cities. Likewise, many of these urban areas also have levels of fine particulate matter ($PM_{2.5}$) above the level that is recommended by the World Health Organization (WHO). In fact, there is no safe level of air pollution for people to breathe in and health effects have been evidenced at levels far below both the EU legal limits and WHO guidelines.

Home to over 1.5 million people, Liverpool City Region (LCR) – made up of Halton, Knowsley, Liverpool, St. Helens, Sefton and Wirral – is one of these harmfully polluted areas.[2] Nearly 70% of the local authorities within the combined authority have roadside levels of NO_2 that breach legal limits, and every local authority has an area with levels of $PM_{2.5}$ over that recommended by the WHO.[3]

This briefing outlines new research commissioned by the British Lung Foundation (BLF) and carried out by King's College London (KCL) into the health and economic impacts associated with current and future pollution concentrations in LCR.[4] The KCL study is based on similar methodology from previous research in London, Greater Manchester and Birmingham. It's the first time that new methodology, recommended by the government's medical advisory committee, has been used to work out the health impacts of air pollution in a combined authority region.[5] It found:

- Up to 1,040 deaths a year can be linked to exposure to $PM_{2.5}$ and NO_2 in LCR.
- Air pollution costs the LCR economy an average of £480 million each year.
- An eight-year-old living in LCR today could still have their life cut short by up to five months, even if pollution decreases in line with projected future improvements.
- People living within the poorest communities in LCR are more likely to be exposed to higher levels of air pollution and would benefit the most from improvement in air quality.
- The health burden from air pollution is spread across local authorities in LCR.

This study shines a light on the health burden from air pollution that is being felt across LCR and shows that even if levels of air pollution decrease to projected levels by 2030, substantial health effects will remain. Given that the region also has some of the highest levels of lung disease and deprivation in the country and that these groups tend to be the most vulnerable to toxic air, it's even more critical that local politicians take urgent action to tackle this problem.

We recommend that Liverpool and Sefton Councils should:

1. Introduce charging Clean Air Zones across the most polluted parts of Liverpool and Sefton, as quickly as possible. The government's own research shows that charging Clean Air Zones can be the quickest way to bring pollution down. That's why ambitious zones must urgently be put in place across the most polluted parts of Liverpool and Sefton. This should include charging for the most polluting private cars as well as lorries, vans and taxis.
2. Publish local clean air plans that deliver maximum benefit to human health, as quickly as possible. These plans should outline how people's exposure to toxic air will be reduced and how the most vulnerable people will be protected where they live, learn and play.

Liverpool City Region Combined Authority (LCRCA), in partnership with the six local authorities, should:

3. Set out a regional air quality plan that commits to reach levels of $PM_{2.5}$ recommended by the WHO by 2030. This plan should set out a public health framework to achieve this across local authorities and be embedded across health, environment, education, strategic planning and transport teams.
4. Roll out a Clean Air for Children programme. Children are among the most vulnerable to toxic air, so it's essential that a region-wide programme is put in place to protect them. This should include audits of schools and nurseries in polluted areas to identify which tailored solutions best solve local challenges, and funding for local areas to put these solutions in place, such as school streets.
5. Prioritise air quality and public health improvement across all regional strategies, particularly for planning and economic growth, and reflect this in funding allocation. This should include planning policies that reduce reliance on road transport and promote increased use of walking, cycling and public transport.

To support this and deliver the urgent changes required, the UK government should:

6. Enact ambitious new clean air laws that commit to achieving WHO limits for $PM_{2.5}$ by 2030 and strengthen local authorities' powers to deliver clean air in their communities.
7. Set out a national healthy lungs and clean air strategy that gives a public health framework for protecting the most vulnerable from toxic air and a roadmap to reach WHO levels by 2030. This should include ring-fenced funding for interventions that protect vulnerable groups and training for health care professionals.
8. Provide financial support so that people can switch their polluting vehicles for cleaner modes of travel such as electric vehicles, retrofitted freight vehicles, e-bikes or public transport. This could be done through mobility credits and should be targeted to people on the lowest incomes, small businesses and people with long-term lung conditions.

Introduction

Air pollution is at illegal and unsafe levels across LCR. It can pose a serious risk to our health, particularly for people living with lung conditions, older people and children.

> “Air pollution can now be linked to thousands of strokes, cardiac arrests and asthma attacks a year, so it’s clear that the climate emergency is in fact also a health emergency.”
>
> **Simon Stevens, CEO, NHS England**

Air pollution is linked to a wide range of health problems, including lung disease, stroke, and cancer. Breathing in air pollution is bad for everyone and has been linked to 36,000 early deaths a year in the UK.[6] For the 12 million people in the UK who live with a lung condition, such as asthma or COPD, toxic air poses a real and immediate threat to their health. A spike in air pollution levels can lead to symptoms getting worse, flare-ups and even the risk of going to hospital.[7,8] Additionally, high air pollution exposure can stunt the growth of children’s lungs,[9] and increase the risk of childhood respiratory infections.[10] While not yet conclusive, it may also play a role in the causation of new cases of asthma and emerging evidence has shown that it can be linked to diabetes,[12] dementia[13] and poor pregnancy outcomes.[14,15,16]

LCRCA is responsible for numerous policy areas that are essential to deliver cleaner air, including transport, planning, regeneration and regional funding allocation. There are also future plans to bring health and social care within its remit. The combined authority secured these powers in a devolution agreement with the government in 2015 and was allocated £900 million over 30 years to deliver its plans. The combined authority has identified economic and inclusive growth as a key priority for the region given it still faces considerable challenges relating to workforce productivity, labour market inactivity and attracting investment.[17] Improving air quality will not only be critical to deliver transport and health outcomes but should also be embedded in all plans to deliver a more prosperous and thriving LCR.

This briefing has been written to bring together existing evidence and new research from KCL, to help support local policy makers identify the changes that are needed while they develop their clean air plans. It provides a compelling case for urgent local action but critically this will also need to be supported by a range of central government actions outlined in the recommendations of this report.

Health impacts of toxic air in Liverpool

In Liverpool on high air pollution days:

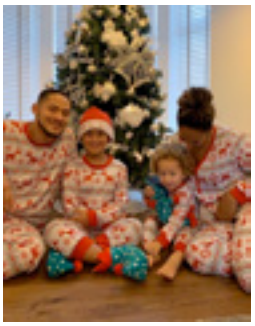
- an extra seven children are hospitalised with asthma
- 12 more children with asthma experience increased symptoms like coughing or breathlessness

And in the long term:

- Air pollution stunts lung growth in children by 4.6% by the age of 15 (they may never recover this loss of lung function and could be at risk of health problems throughout their lives)
- Cutting air pollution in Liverpool by one fifth would result in 17 fewer lung cancer cases each year
- Cutting air pollution in Liverpool by one fifth would result in three fewer babies born underweight each year.

King's College London (2019) Personalising the health impacts of air pollution: interim statistics summary for a selection of statements, www.erg.kcl.ac.uk/Research/docs/personalised-health-impacts.pdf

Safiyah Kamarudin – mum of two and clean air campaigner



"I think it's about time that Liverpool City Region took urgent action to clean up our air. With the Clean Air Parents' Network, I've been to parliament to ask MPs to put pressure on the government to provide funding to do this. But if local politicians are not ambitious enough to go further than just complying with the law, we are storing up massive health and economic problems for future generations.

The thing that worries me most about air pollution is the long-term health effects. My children could be at risk of developing problems because of their exposure to poisons in the air they breathe every day. We need to raise awareness of this and health needs to be the top priority."

Pam Parry – Clinical Team Leader, BLF Helpline, Liverpool

"I'm really concerned about the increasing levels of air pollution in Merseyside. Our area has a high prevalence of chronic lung disease and because we cannot see the particulates, we are unaware of what exactly we are breathing in.

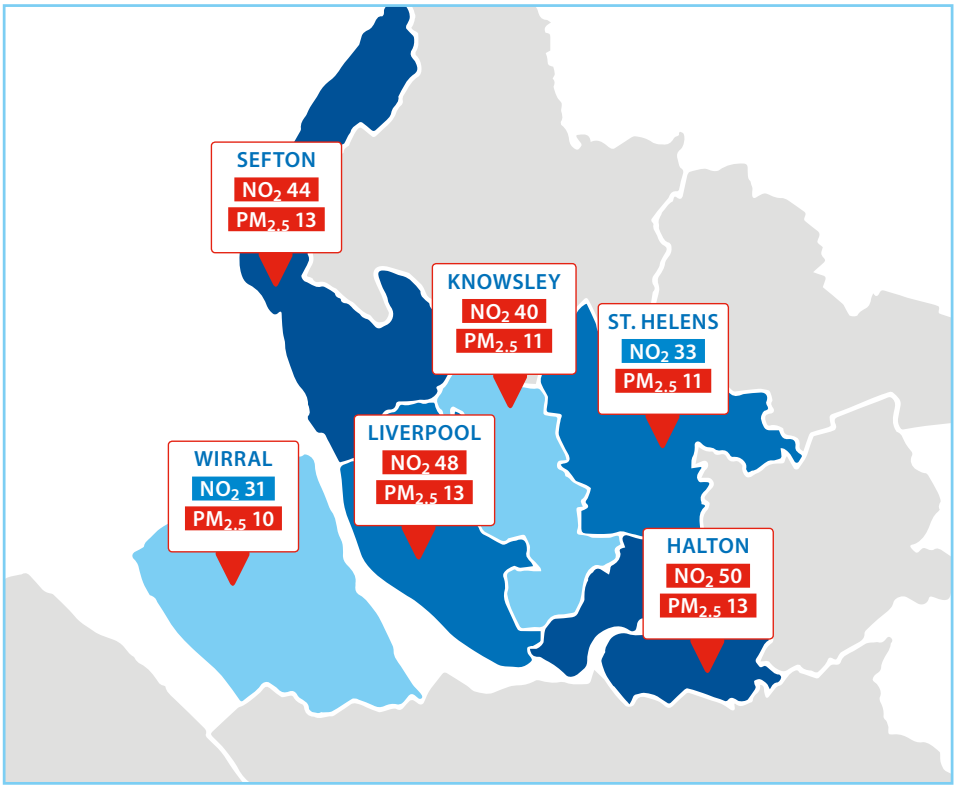
We have many callers who have increased symptoms when they go outside and I'm very concerned about children in buggies who are so near to car exhausts. I fully support Clean Air Zones in our towns and cities and around our schools. This will reduce the burden of lung disease on the NHS in the future."

Background: toxic air in Liverpool City Region

Every local authority that makes up LCR has an area with unsafe or illegal levels of air pollution

Every local authority that makes up LCR has an area that either breaches the legal limit for NO_2 or exceeds the WHO recommended limit for $PM_{2.5}$. This is evidenced in local air quality plans for Halton,[18] Knowsley,[19] Liverpool,[20] St. Helens,[21] Sefton[22] and Wirral[23] as well as modelled government data (see figure 1). And critically, there is no safe level of exposure to air pollution and health impacts have been evidenced far below both the WHO guidelines and EU limit values. So, policy makers should in fact be aiming far below these limits to deliver maximum health benefits.

Figure 1: Highest 2018 average annual roadside concentration levels of NO_2 (µg/m³) and $PM_{2.5}$* (µg/m³)



- Over the average annual legal limit of 40µg/m³ for NO_2 or on/over the WHO recommended limit of 10µg/m³ for $PM_{2.5}$
- Under the average annual legal limit of 40µg/m³ for NO_2 or under the WHO recommended limit of 10µg/m³ for $PM_{2.5}$ – however note there is no safe level of exposure to pollution

* $PM_{2.5}$ only from manmade sources not including natural sources

** Halton data taken before building of the Mersey Gateway, so we do not yet know how this has affected air pollution levels

Additionally, BLF data show that the risk of lung disease is higher than the national average in all the local authorities across the region (see figure 2).[24] NHS data shows that there are over 95,000 people currently living with COPD and over 44,000 living with asthma across the city region (see table 1).[25] Given people with lung conditions are at increased risk from air pollution exposure, these data show that the case for action in LCR is particularly important and could reap rewards for respiratory health outcomes.

Figure 2: Lung disease relative risk across LCR, taken from British Lung Foundation (2016) Battle for Breath

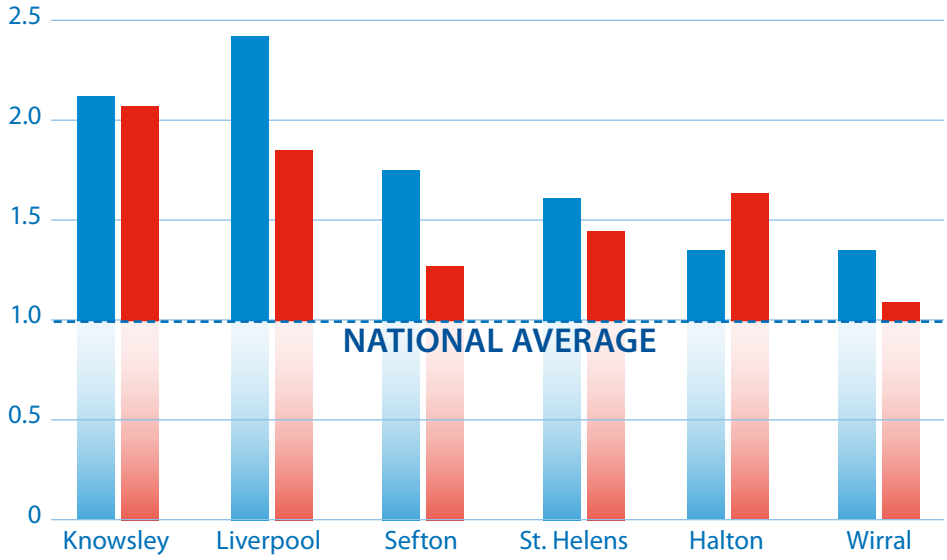


Table 1: Lung disease prevalence based on number of people registered with asthma and COPD by NHS Clinical Commissioning Groups in LCR and relative risk of lung disease across LCR taken from a national dataset produced for the British Lung Foundation's Battle for Breath report.

	Asthma admissions (relative risk) 1= national average	COPD mortality (relative risk) 1= national average	Asthma register 2017–2018	COPD register 2017–2018
Knowsley	2.137	2.046	9,508	5,873
Liverpool	2.443	1.869	30,200	16,208
Sefton	1.729	1.263	9,723	4,781
St. Helens	1.59	1.426	14,546	5,902
Halton	1.392	1.643	8,977	3,658
Wirral	1.373	1.253	22,455	8,533
			95,409	**44,955**

Air pollution exposure is a major health inequality issue

Research shows that young families and poorer households tend to be disproportionately represented in areas with the highest concentrations of pollution in Britain.[26] The most deprived communities also tend to have the lowest levels of car ownership – so they are among the most impacted by the health effects but also the least responsible for the problem.[27] LCRCA's transport strategy supports these findings, and states, "there is a direct link between more affluent areas and higher rates of car usage, where car ownership rates are higher. Equally, less affluent areas will often experience the impact of these car borne trips through their communities."[28] Car ownership in Knowsley and Liverpool is significantly below national levels,[29] and these two local authorities are the most deprived in LCR and amongst the most deprived in England.[30]

When we look at ward level data in Liverpool, the percentage of households with no ownership or access to cars, is higher in known pollution hotspots, such as Kensington and Fairfield (63%) and Everton (65%) compared to 46% for Liverpool as a whole and 27% nationally.[31,32,33] This suggests that deprived communities living in LCR are likely to reap the most health benefit from tackling toxic air and could be less impacted by policies that charge private car usage.

Road transport is a major contributor to LCR's toxic air

Government data show that 80% of NO_2 at the roadside comes from vehicle emissions, and that diesel vehicles play a major role.[34] Concerningly, the number of cars licensed in Merseyside increased by 6.3%, in relation to a population increase of only 1.6% in the ten years between 2002–2012.[35] Conversely, rates of walking and cycling remain low in LCR (typically accounting for around 4.5% and 1% of all trips, respectively).[36] In comparison, national statistics from 2018 show that walking accounted for 27% of total trips and cycling accounted for 2% of all trips in England.[37]

Tackling air pollution is critical to deliver LCRCA's strategic ambitions

Improving air quality will be integral to achieve a number of the goals set out in LCRCA's strategic plan and transport strategy, particularly their ambitions to:

- Improve transport, energy and digital infrastructures, and protect and enhance our cultural and environmental assets.
- Regenerate deprived communities and promote health and wellbeing across the City Region.[38]
- Develop a green and healthy transport system, which supports the development of new and existing communities, and the move to a zero carbon LCR by 2040.[39]

In October 2019 both Liverpool City Council and LCR recognised the scale of this national health crisis and committed to support UK100's Clean Air Declaration, stating:

"Urgent action to eliminate air pollution must be a national priority and we as local leaders and business leaders are committed to prioritising action to protect people's health and to tackle the Climate Emergency. Inadequate investment, a lack of national frameworks and consistent approaches, and the absence of necessary powers are stifling our ability to act."[40]

This briefing outlines the urgent case for change in LCR. Tackling toxic emissions across LCR is essential to improve air quality to meet both the legal limit values and the WHO guidelines, and ultimately to achieve the lowest possible effect on people's health. This will be essential to prevent future lung conditions, reduce health inequality and facilitate a thriving and greener LCR.

> "Only through working in partnership between local authorities, business and government can we take urgent action to eliminate air pollution and ensure clean air for all."
>
> from Polly Billington of UK100

Findings from King's College London study

1) Up to 1,040 deaths a year can be linked to exposure to $PM_{2.5}$ and NO_2 in LCR.

In 2011 in LCR the equivalent of between 800 to 1,040 deaths are attributable to manmade $PM_{2.5}$ and NO_2.[41] As with deaths in the general population, most of these occur at older ages. The KCL study didn't look at cause of death, but the general literature indicates that they are likely to be from cardiovascular and respiratory disease, including lung cancer.

2) Air pollution in LCR has an annualised economic impact of up to £480 million on average per year.

Despite the projected future improvements in air pollution concentrations from 2011 to 2030, the economic health impact costs in LCR over a lifetime are still between £170 million and £480 million on average per year.

3) An eight-year-old living in LCR today could still have their life cut short by up to five months, even if pollution decreases in line with projected future concentrations.

If air pollution reduces in line with current projections across the region then major health benefits would be felt, but it still wouldn't go far enough. This suggests policymakers need to go further to set out more ambitious emissions reductions, and therefore projections that deliver maximum benefit to human health.

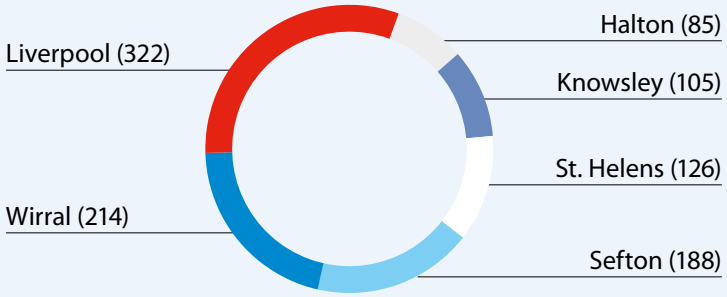
If air pollution improves in line with the way it's projected to from 2011–2030,[42] then the population in LCR would gain around 350,000 to 370,000 life years over a lifetime (until 2134).[43] This is compared to if it remained at 2011 concentrations. This means, that on average life expectancy of a child born in LCR in 2011 would improve by around 2 to 2.5 months.

However, even under these projected future improvements the population would still be losing between 0.3 to 0.8 million life years in LCR. Or put another way, an eight-year-old in 2019 would still be estimated to die 1.5-5.5 months early on average,[44] if exposed over their lifetimes to projected future air pollution concentrations in LCR.

4) The health burden linked to air pollution is spread across local authorities in LCR.

The mortality burden from air pollution is highest in Liverpool, followed by Wirral and Sefton, and is felt across all local authorities.[45]

Figure 3: Breakdown of attributable deaths from air pollution exposure across LCR



5) The most vulnerable individuals within LCR would benefit the most from improvements in air quality.

The most vulnerable individuals – people living in the poorest communities, people with long-term health problems and young families – within LCR are more likely to be exposed to higher levels of air pollution and would benefit the most from further reduction of air pollution.

Furthermore, Liverpool has the highest population, highest level of deprivation and highest attributable death out of the six local authorities forming LCR and would benefit greatly from a reduction in air pollution concentrations (see table 2).

Table 2: Mortality burden, population weighted air pollution concentration, and overall index of multiple deprivation by local authorities in LCR

Local authority	Attributable deaths per year from manmade $PM_{2.5}$ and NO_2 (upper range estimates)	µg m^3 (annual) by local authority in 2017	NO_2 population weighted concentration (in µg m^3) (annual) by local authority in 2017	Overall index of multiple deprivation – average rank score (1=most deprived, 326 = least deprived in England)
Liverpool	322	8.12	18.41	4
Wirral	214	6.7	12.22	66
Sefton	188	6.53	11.78	76
St. Helens	126	7.67	14.84	36
Knowsley	105	8.14	17.5	2
Halton	85	7.98	15.92	27
Liverpool City Region	**1,040**			

Briefing conclusion and recommendations

This new study from KCL and existing evidence demonstrates the urgent need to clean up the air we all breathe and protect the health of everyone living in LCR. It shows that the health and economic impacts of toxic air are being acutely felt across LCRCA and that the most vulnerable communities are likely to reap the most health rewards from effective policy action. When combined with existing evidence it sets out a stark and compelling case for urgent action to reduce toxic emissions and reduce people's exposure.

The findings in the KCL study are likely to be an underestimate as they only look at the effect of air pollution on deaths and loss of life expectancy. This included all causes of deaths grouped together so covers respiratory, lung cancer and cardiovascular deaths for which there is good evidence for an effect of air pollution. It did not, however, cover the effect of air pollution on health where this does not result in death. So well-established effects, such as respiratory and cardiovascular hospital admissions, effects on asthma, low birth weight, and other areas where research is emerging, such as dementia, are not included. Their inclusion in future modelling and research would provide an even more in-depth health assessment, and further demonstrate the benefit of policies that reduce toxic air.

Key recommendations

1. Charging Clean Air Zones established in the most polluted areas of Liverpool and Sefton, as quickly as possible

Why is this needed? To meet legal limits and protect our health as quickly as possible. Both Liverpool and Sefton have been ordered by central government to develop local clean air plans to bring down levels of NO_2 as quickly as possible in order to meet EU legal limits, as a result of mandated court action against government since 2015.

Charging Clean Air Zones are the quickest way to tackle the problem. The government's own evidence shows that charging the most polluting vehicles, including private cars, for entering Clean Air Zones can deliver the quickest reductions to levels of NO_2.

By who? Liverpool City Council and Sefton Council

2. Local clean air plans that deliver maximum benefit to human health, as quickly as possible

Why is this needed? A holistic clean air plan is needed across the local authorities to reduce people's exposure to toxic air. This should include air pollution alerts and public health messaging for vulnerable groups, as well as enforcement measures for road, air and water transport as well as non-road mobile machinery, infrastructure and construction.

By who? Liverpool City Council and Sefton Council

3. A Liverpool City Region air quality plan that commits to reach levels of fine particulate matter recommended by the WHO by 2030, as a minimum

Why is this needed? Current legal standards for $PM_{2.5}$ are not strong enough and ambition will need to be set much higher to protect public health. Evidence has shown that there is no safe level of exposure to air pollution, so LCRCA should be aiming far below even the WHO's recommended level.

A public health framework to tackle air pollution is needed across the region. This will need to include major improvements to air quality monitoring and data collection, as well as integration with local respiratory health care plans, such as the new Merseyside sustainability and transformation plan.

By who? LCRCA

4. A regional Clean Air for Children programme

Why is this needed? Children are among the most vulnerable to toxic air, so it's essential that a region-wide and evidence-based programme is put in place to protect them. This should include audits of schools and nurseries in polluted areas to identify which tailored solutions best solve local challenges, and funding for local areas to put these solutions in place, such as school streets or active travel schemes.

By who? LCRCA

5. Prioritisation of air quality and public health improvement across all regional strategies

Why is this needed? Future economic growth plans and major planned developments must prioritise air quality improvement, such as the plans for future port regeneration and economic development of the region.

By who? LCRCA

6. New clean air laws that set legal limits in line with WHO standards and set out plans to protect public health

Why is this needed? Current legal limits are inadequate and new laws are needed to strengthen local authorities' powers to tackle toxic air. Legal limits for $PM_{2.5}$ are currently set twice as high as the guideline recommended by the WHO. New legislation should prioritise changing this.

By who? UK government

7. Set out a national healthy lungs and clean air strategy

Why is this needed? The current clean air strategy needs to be refreshed to set out a plan to protect public health and a roadmap for local authorities to reach WHO levels by 2030. This should include ring-fenced funding for interventions that protect vulnerable groups and training for health care professionals.

By who? UK government

8. Provide financial support so that people can switch their polluting vehicles for cleaner modes of travel

Why is this needed? People on low incomes, people with long-term lung conditions and smaller businesses will require financial support to choose cleaner modes of travel. This could be done through a national mobility credits system that could go toward electric vehicles, e-bikes or public transport.

By who? LCRCA and UK government

Reducing air pollution is critical to deliver a thriving, more inclusive and healthier LCR. By joining together respiratory health and transport plans, and prioritising air quality in planning and economic growth strategies, co-benefits could be maximized across policy making and ultimately, lives could be saved. The urgent need for action is clear, and its benefits will not just be felt now but for generations to come.

Appendix:

Methodology and limitations from KCL study: Liverpool City Region Combined Authority Health and Economic Impact Assessment

a) Health assessment

It is now well established that adverse health effects, including mortality, are statistically associated with outdoor ambient concentrations of air pollutants. Moreover, toxicological studies of potential mechanisms of damage have added to the evidence such that many organisations consider the evidence strong enough to infer a causal relationship between the adverse health effects and the air pollution concentrations.

The concentration-response functions used and the spatial scales of the input data are given in table 13, table 14 and table 15 in the appendix of the full report. The concentration-response functions are based on the latest advice from the Committee on the Medical Effects of Air Pollutants in 2018 (COMEAP, 2018a). Previously, burden calculations were based only on concentrations of $PM_{2.5}$ (COMEAP, 2010). The new COMEAP report considers whether there is an additional burden or impact from NO_2 or other pollutants with which it is closely correlated.

Results are given with and without a cut-off[46] of 7 µg m^3 for $PM_{2.5}$ and 5 µg m^3 for NO_2 in the full report, but in this briefing the 'cut-off' figures have been used. This study uses this epidemiological evidence to estimate the health impacts of the changes in air pollutant concentrations discussed in the air quality modelling section below.

b) Economic assessment

Economists assign monetary values to the health benefits in order to compare the benefits with the real costs of implementing a package of policies. The largest proportion of the monetary value comes from a survey asking 170 members of the public how much they would be willing to pay to reduce their risk of experiencing a loss of one month of life (in good health) due to air pollution (Chilton et al, 2004). Added up across time, people and the total health effects, this is then used to represent the amount society thinks should be spent to reduce these risks. NHS costs and loss of productivity are not included.

In undertaking a valuation in monetary terms of the mortality impacts described in the previous section, we have used the methods set out in an earlier report from Environmental Research Group (ERG) on the health impacts of air pollution in London (Walton et al., 2015) and in an ERG project funded by NIHR and reported in their journal library (Williams et al., 2018b). This built on previous work by the study team for Defra and the Inter-departmental Group on Costs and Benefits (IGCB) within the UK government. The methods are therefore consistent with those used in government in the UK.

Life years lost were valued using values recommended in Defra guidance,[47] updated to 2014 prices. Consistent with this guidance, values for future life years lost were increased at 2% per annum, then discounted using the declining discount rate scheme in the HMT Green Book.[48] The economic impact was then annualised back to 2014, i.e. divided by the total number of years but front-loaded to take into account that benefits accrued sooner are valued more than those accrued later

This report uses what are called 'annualised' figures - a term for an average per year when the result is not the same every year. Economists assign monetary values to the health benefits of reducing air pollution in cost-benefit analysis in order to compare with the costs of implementing a package of policies. The monetary value for each individual health outcome is then added up across time, people and the total health effects. They are not actual costs but a measure of the amount of money society believes it would be reasonable to spend on policies to reduce air pollution[49] (to avoid the adverse health effects of the remaining pollution) or was reasonable to have spent on policies that have already reduced air pollution.

From 1kmx1km grid data to ward concentration

1. Maps of particulate matter with diameter <2.5 mm ($PM_{2.5}$) and NO_2 annual average concentration were produced for each of the six combined local authorities forming LCR. To do this, ERG downloaded $PM_{2.5}$ and NO_2 air pollution data in LCR from the Defra Local Air Quality Management webpages.[50] The 2011 and the 2017 to 2030 data were downloaded from the 2011 and newly released 2017 model predictions. Using these data of regular 1km by 1km pollutant points we then produced mean spatially-weighted concentrations for each Ward, using the Ward boundaries from the government's Open Data portal.

From ward to population-weighted local authority concentration

2. To define population-weighted average concentration (PWAC), population-weighting was done from ward to local authority level. A simple average concentration across wards gives equal weight to ward with higher and lower population density. Population-weighting takes this into account. The local authority population-weighted means were then used directly in the health impact calculations across all six local authorities (this process allows one health calculation per local authority rather than calculations in each separate ward).

Limitations

The main report presents a wider range of uncertainty around the results for the mortality burden, mortality impacts and economic costs than the figures shown here.

The study was focused on air pollution changes within LCR. Reductions in emissions will also have benefits for air pollution concentrations in the wider region (Northern England and beyond). For example, reductions in NOx emissions will reduce nitrate concentrations and thus $PM_{2.5}$ concentrations in the wider region. The health benefits of this are not reflected here, although they are likely to be smaller than those in LCR itself.

There will be further impacts from ozone concentrations. The long-term ozone exposure NO_2 (representative of summer smog ozone concentrations metric) is projected to decrease over time compared with 2011 but less than other pollutants such as NO_2 and $PM_{2.5}$.

This study addressed the effect of air pollution on deaths and loss of life expectancy. This included all causes of death grouped together so covers, for example, respiratory, lung cancer and cardiovascular deaths for which there is good evidence for an effect of air pollution. It does not, however, cover the effect of air pollution on health where this does not result in death. So well-established effects (such as respiratory and cardiovascular hospital admissions, effects on asthma, low birth weight etc) and other outcomes more recently potentially linked with air pollution (such as dementia) are not included. Their inclusion would increase the benefit of policies to further reduce air pollution.

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41 The original studies were analysed in terms of 'time to death' aggregated across the population. Strictly, it is unknown whether this total change in life years was from a smaller number of deaths fully attributable to air pollution or a larger number of deaths to which air pollution partially contributed. The former is used with the phrase 'equivalent' to address this issue. See COMEAP (2010) for a fuller discussion.

42 2011 and 2017 concentrations representing current reference years and any future years up to 2030 have been estimated from the 2017 baseline.

43 It is not possible to calculate the full result for gains in life expectancy until everyone in the initial population has died (105 years from 2030), necessitating follow-up for a lifetime even if the pollution changes are only for the next decade or so.

44 The range is according to whether indicator pollutant is taken as $PM_{2.5}$ or NO_2, whether or not there is a cut-off concentration below which no effects are assumed and gender.

45 These results use recommendations from COMEAP, 2018. For each of the four individual cohort studies that included multi-pollutant model results, the burden results were estimated separately using mutually adjusted summary coefficients for $PM_{2.5}$ and NO_2 and then the adjusted $PM_{2.5}$ and NO_2 results were summed to give an estimated burden of the air pollution mixture. Examples of the calculations for each study for individual local authority and LCR of 2011 levels of NO_2 and $PM_{2.5}$ can be found in the appendix of the full report in table 27 and table 28. The uncertainty of each separate study was not quantified (COMEAP, 2018) but it is worth noting that each of the individual results also has uncertainty associated with it.

46 Cut-off is a term used for the concentration below which it is unclear whether or not epidemiological evidence supports the existence of an effect. This does not mean there is no effect below the cut-off, just that the numbers of data points are too small to be sure one way or the other.

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